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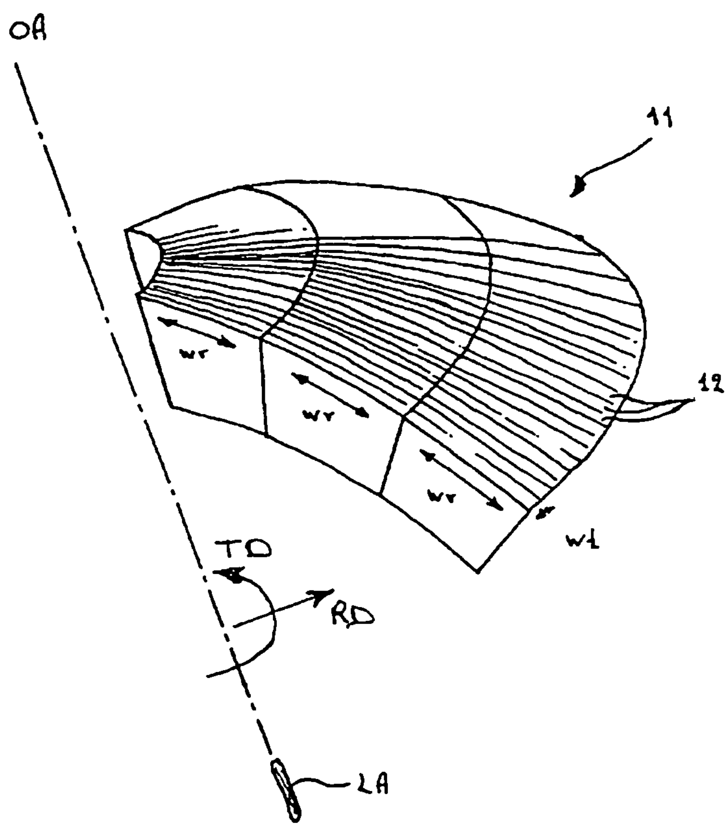

(57) Abstract: A lithographic projection apparatus has a discharge plasma radiation source (LA) that is contained in a vacuum chamber (10). The radiation source is to generate a beam (PB) of EUV radiation. A chamber wall of the vacuum chamber incorporates a channel structure comprising adjacent narrow channels (11) that are substantially parallel to a propagation direction of the radiation beam and have a width that decreases or increases along the beam axis in accordance with the beam vergence. This structure passes the beam to another subsequent vacuum chamber (20) maintained at a much higher vacuum level (lower pressure).

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ILLUMINATION SYSTEM WITH VACUUM CHAMBER WALL HAVING TRANSPARENT STRUCTURE

The invention relates an illumination system comprising:

a radiation source constructed to generate a beam of radiation; and two vacuum chambers separated by a chamber wall incorporating a channel structure comprising adjacent narrow channels separated by walls that are substantially parallel to a propagation direction of said radiation so as to pass said radiation from one of said vacuum chambers to the other one, said propagation direction being substantially along an optical axis of the illumination system.

The invention also relates to a lithographic projection apparatus comprising such an illumination system and to a method of manufacturing devices using such an apparatus.

For the sake of simplicity, the projection system of the apparatus may hereinafter be referred to as the "lens"; however, this term should be broadly interpreted as encompassing various types of projection systems, including refractive optics, reflective optics and catadioptric systems, for example. In addition, the first and second object tables may be referred to as the "mask table" and the "substrate table", respectively. Further, the lithographic apparatus may be of a type having two or more mask tables and/or two or more substrate tables. In such "multiple stage" devices the additional tables may be used in parallel, which means that preparatory steps may be carried out on one or more stages while one or more other stages are being used for exposures. Twin stage lithographic apparatus are described in International Patent Applications WO 98/28665 and WO 98/40791, for example.

Lithographic projection apparatus can be used, for example, in the manufacture of integrated circuits (ICs). In such a case, the mask (reticle) may contain a circuit pattern corresponding to an individual layer of the IC. This pattern can be imaged onto a target area (comprising one or more dies) on a substrate (silicon wafer) which has been coated with a layer of radiation-sensitive material (resist). In general, a single wafer will contain a whole network of adjacent target areas, which are successively irradiated via the mask, one at a time. In one type of lithographic projection apparatus, each target area is exposed at one go by illuminating the entire mask pattern. Such an apparatus is commonly

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referred to as a wafer stepper. In an alternative apparatus, which is commonly referred to as a step-and-scan apparatus, each target area is exposed by progressively scanning the mask pattern through the projection beam in a given reference direction (the "scanning" direction) while synchronously scanning the substrate table parallel or anti-parallel to this direction. Since, in general, the projection system will have a magnification factor M (generally < 1), the speed V at which the substrate table is scanned will be a factor M times that at which the mask table is scanned. More information with regard to lithographic devices as here described can be gleaned from International Patent Application WO 97/33205.

In a lithographic apparatus the size of features that can be imaged onto the substrate is limited by the wavelength of the projection radiation. To produce integrated circuits with a higher density of devices, and hence higher operating speeds, it is desirable to be able to image smaller features. Whilst most current lithographic projection apparatus employ ultraviolet light generated by mercury lamps or excimer lasers, it has been proposed to use shorter wavelength radiation of around 13 nm. Such radiation is termed extreme ultraviolet radiation, also referred to as XUV or EUV radiation. XUV generally refers to the wavelength range from several tenths of nanometer to several tens of nanometers, combining the soft x-ray and vacuum UV range. EUV is normally used in conjunction with lithography (EUVL) and refers to a radiation band from approximately 5 to 20 nm, i.e. part of the XUV range.

Possible sources for EUV radiation include, for instance, laser-produced plasma sources, discharge plasma sources, or synchrotron radiation from electron storage rings. An outline design of a lithographic projection apparatus using synchrotron radiation is described in "Synchrotron Radiation Sources and Condensers for Projection X-Ray Lithography", J.B. Murphy et al, Applied Optics, Vol. 32, No. 24, pp. 6920-6929 (1993). Apparatus using discharge plasma sources are described in: "Development of an EUV (13.5 nm) Light Source Employing a Dense Plasma Focus in Lithium Vapor", W. Partlo et al, Proc. SPIE 3997, pp. 136-156 (2000).

So-called "undulators" and "wigglers" have been proposed as an alternative source of extreme ultraviolet radiation. In these devices, a beam of electrons traveling at high, usually relativistic, speeds, e.g. in a storage ring, is caused to traverse a series of regions in which magnetic fields perpendicular to the beam velocity are established. The directions of the magnetic field in adjacent regions are mutually opposite, so that the electrons follow an undulating path. The transverse accelerations of the electrons following the undulating path

cause the emission of Maxwell radiation perpendicular to the direction of the accelerations, i.e. in the direction of the non-deviated path.

Radiation sources may require the use of a rather high partial pressure of a gas or vapor to emit XUV radiation, such as discharge plasma radiation sources referred to above. In a discharge plasma source a discharge is created in between electrodes, and resulting partially ionized plasma generates radiation in the XUV range. The very hot plasma is quite often created in xenon (Xe), since xenon plasma radiates in the EUV range around 13.5 nm. For an efficient EUV production, a typical pressure of 0.1 mbar is required near the electrodes of the radiation source. A drawback of having such a rather high Xe pressure is that Xe gas absorbs EUV radiation. For example, 0.1 mbar Xe transmits over 1 m only 0.3% EUV radiation having a wavelength of 13.5 nm. It is therefore required to confine the rather high Xe pressure to a limited region around the source. To reach this the source can be contained in its own vacuum chamber that is separated by a chamber wall from a subsequent vacuum chamber in which the collector mirror and illumination optics may be contained. However, an EUV radiation transparent opening is needed to pass the EUV radiation emitted by the source to the next vacuum chamber. Since a large opening in the wall, required to collect sufficient EUV radiation, would cause an elevated pressure in the next vacuum chamber, the opening might be closed off using a thin window, e.g. having a thickness of a few micron or less, which is (partially) transparent for EUV radiation. Such a thin window will, however, not survive the heat load from the high-power EUV radiation source that is needed for EUV lithography.

It is an object of the present invention is to provide an illumination system, especially but not exclusively suited for a lithographic projection apparatus, which system does not suffer from the above mentioned problems. The illumination system as defined in the opening paragraph is characterized in that that a width of said channels increases or decreases along said optical axis in accordance with passing of a diverging or converging beam of radiation, respectively.

The channel structure constitutes a vacuum chamber wall that is transparent for EUV radiation and further presents a gas barrier so as to be able to maintain different vacuum levels in vacuum chambers on both sides of the vacuum chamber wall.

The illumination system may be further characterized in that said channel structure comprises a honeycomb structure.

Preferably the illumination system is characterized in that a cross-sectional

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dimension of said channels in a radial direction perpendicular to said optical axis is larger than another cross-sectional dimension of said channels in a tangential direction around said optical axis.

According to a further aspect of the invention, the channel walls are reflective for the projection beam.

This measure prevents that source radiation incident on these walls will be lost. In a channel structure for EUV radiation the walls may be covered by a molybdenum layer.

The invention also relates to a lithographic projection apparatus comprising:

- an illumination system constructed and arranged to supply a projection beam of radiation;
- a mask table constructed to hold a mask;
- a substrate table constructed to hold a substrate; and
- a projection system constructed and arranged to image an irradiated portion of the mask onto a target portion of the substrate. This apparatus is characterized in that the illumination system is a system as described herein before.

The invention also relates to a method of manufacturing a device, such as an IC, comprising device features in at least one layer of a substrate , which method comprises at least one set of at least the following successive steps:

- providing a mask pattern comprising pattern features corresponding to device feature to be configured in said substrate layer;
- illuminating the mask pattern by means of an illumination system;
- imaging the mask patter by means of a projection system in a resist layer coated on the substrate;
- developing the resist layer, and
- removing material from or adding material to substrate areas, which areas are delineated by the pattern configured in the resist layer. This method is characterized in that use is made of an illumination system as described herein before.

By using the invention the intensity of the projected beam is increased and the quality of the projection system is enhanced, which results in an improved method.

In a manufacturing process using a lithographic projection, a pattern in a mask is imaged onto a substrate, which is at least partially covered by a layer of radiation-sensitive material (resist). Prior to this imaging step, the substrate may undergo various procedures, such as priming, resist coating and a soft bake. After exposure, the substrate may be

subjected to other procedures, such as a post-exposure bake (PEB), development, a hard bake and measurement/inspection of the imaged features. This array of procedures is used as a basis to pattern an individual layer of a device, e.g. an IC. Such a patterned layer may then undergo various processes such as etching, ion-implantation (doping), metallization, oxidation, chemically-mechanical polishing, etc., all intended to finish off an individual layer. If several layers are required, then the whole procedure or a variant thereof, will have to be repeated for each new layer. Eventually, an array of devices will be present on the substrate (wafer). These devices are then separated from one another by a technique such as dicing or sawing, whence the individual devices can be mounted on a carrier, connected to pins, etc. Further information regarding such processes can be obtained, for example, from the book "Microchip Fabrication: A Practical Guide to Semiconductor Processing", Third Edition, by Peter van Zant, McGraw Hill Publishing Co., 1997, ISBN 0-07-067250-4.

Although specific reference has been made herein above to the use of the apparatus according to the invention in the manufacture of ICs, it should be explicitly understood that such an apparatus has many other possible applications. For example, it may be employed in the manufacture of integrated optical systems, guidance and detection patterns for magnetic domain memories, liquid-crystal display panels, thin-film magnetic heads, etc. The skilled artisan will appreciate that, in the context of such alternative applications, any use of the terms "reticle", "wafer" or "die" in this text should be considered as being replaced by the more general terms "mask", "substrate" and "target area", respectively.

Further, this description concentrates on lithographic apparatus and methods employing a mask to pattern the radiation beam entering the projection system and it should be noted that the term "mask" should be taken in a broad context of lithographic apparatus and methods. "Mask" should be interpreted as generally referring to generic "patterning means" to pattern the said radiation beam. The terms "mask" and "patterning means" as here employed refer broadly to means that can be used to endow an incoming radiation beam with a patterned cross-section, corresponding to a pattern that is to be created in a target portion of the substrate. The term "light valve" has also been used in this context. Generally, the said pattern will correspond to a particular functional layer in a device being created in the target portion, such as an integrated circuit or other device. The term "mask table" should be broadly interpreted as any means for holding the "patterning means". Besides a mask plate or reticle on a mask table, such patterning means include a programmable mirror array. An example of such a device is an addressable surface having a control layer and a reflective

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surface. The basic principle behind such an apparatus is that (for example) addressed areas of the reflective surface reflect incident light as diffracted light, whereas not addressed areas reflect incident light as non-diffracted light. Using an appropriate filter, the said non-diffracted light can be filtered out of the reflected beam, leaving only the diffracted light behind. In this way, the beam becomes patterned according to the addressing pattern of the addressable surface. The required matrix addressing can be performed using suitable electronic means. More information on such mirror arrays can be gleaned, for example, from United States Patents US 5,296,891 and US 5,523,193. Another patterning means is a programmable LCD array, an embodiment of which is described in United States Patent US 5,229,872.

The invention and its attendant advantages will be further elucidated with the aid of an exemplary embodiment and the accompanying schematic drawings, in which like reference symbols indicate like parts and in which:

Figure 1 shows an embodiment of a lithographic projection apparatus wherein the invention can be used;

Figure 2 shows the various vacuum chambers or compartments, separated by chamber walls of the apparatus of Figure 1;

Figure 3 shows a part of the Figure 2 arrangement in more detail;

Figure 4 shows a perspective view of a part of a channel structure incorporated in a chamber wall shown in Figure 3; and

Figure 5 depicts a further perspective of the extreme ultraviolet radiation transparent structure incorporated in the chamber wall shown in Figure 3.

Figure 1 schematically depicts a lithographic projection apparatus 1 according to the invention. The apparatus comprises:

a radiation system LA, IL for supplying a projection beam PB of EUV radiation;

a first object table (mask table) MT provided with a first object (mask) holder for holding a mask MA (e.g. a reticle), and connected to first positioning means PM for accurately positioning the mask with respect to item PL;

a second object table (substrate table) WT provided with a second object (substrate) holder for holding a substrate W (e.g. a resist-coated silicon wafer), and connected

to second positioning means PW for accurately positioning the substrate with respect to item PL; and

a projection system ("lens") PL (e.g. a refractive, catadioptric or reflective system) for imaging an irradiated portion of the mask MA onto a target portion C (die) of the substrate W.

The apparatus shown in Figure 1 is of a reflective type (i.e. has a reflective mask). However, in general, it may also be of a transmission type, for example.

The radiation system comprises a discharge plasma source LA that produces a beam of radiation. This beam is passed along various optical components included in illumination system ("lens") IL so that the resultant beam PB is collected in such a way as to give illumination of the desired shape and intensity distribution at the entrance pupil of the projection system and the mask.

The beam PB subsequently impinges upon the mask MA. This mask is held by the mask holder provided on the mask table MT. Having been selectively reflected by the mask MA, the beam PB passes through the lens PL. This lens focuses the beam PB onto a target area C of the substrate W. With the aid of the interferometric displacement measuring means IF and positioning means PW, the substrate table WT can be moved accurately, e.g. so as to position different target areas C in the path of the beam PB. Similarly, the positioning means PM and interferometric displacement measuring means IF can be used to accurately position the mask MA with respect to the path of the beam PB. In general, movement of the object tables MT, WT will be realized with the aid of a long-stroke module (course positioning) and a short-stroke module (fine positioning), which are not explicitly depicted in Figure 1.

The depicted apparatus can be used in two different modes:

In step mode, the mask table MT is kept essentially stationary, and an entire mask image is projected in one go (i.e. a single "flash") onto a target area C. The substrate table WT is then shifted in the X and/or Y directions so that a different target area C can be irradiated by the beam PB; and

In scan mode, essentially the same scenario applies, except that a given target area C is not exposed in a single "flash". Instead, the mask table MT is movable in a given direction (the so-called "scan direction", e.g. the Y direction) with a speed v, so that the projection beam PB is caused to scan over a mask pattern. Concurrently, the substrate table WT is simultaneously moved in the same or opposite direction at a speed $V = Mv$, in which

M is the magnification of the lens PL (typically, M = 1/4 or 1/5). In this manner, a relatively large target area C can be exposed, without having to compromise on resolution.

Figure 2 depicts the various vacuum chambers of the lithographic apparatus of Figure 1, the various parts shown in Figure 1 being located in the various chambers shown in Figure 2. The vacuum chambers are separated by walls in which openings are present for passing the projection beam of radiation PB from one vacuum chamber to the next one. In Figure 2 one can distinguish a source chamber 10 containing the source LA, an illumination optics box 20 containing a collector mirror and the illumination optics, a chamber 30 containing the mask table and mask MA, a projection optics box 40 containing the projection system, and a chamber 50 containing the substrate table and substrate W. In the various vacuum chambers a different vacuum level is maintained. The optics boxes requiring the highest vacuum level to keep the reflective optics clean.

The apparatus is provided with a discharge plasma EUV radiation source, which employs a gas or vapor, such as Xe gas or lithium (Li) vapor, in which a very hot plasma is created to emit radiation in the EUV range of the electromagnetic spectrum. The very hot plasma is created by causing partially ionized plasma of an electrical discharge to collapse onto an optical axis of the system, and the region in which the plasma collapses will, in general, have a finite length along the optical axis. The elongated region into which the plasma collapses is designated LA in Figures 2, 3 and 4. Partial pressures of 0.1 mbar Xe, Li vapor or any other suitable gas or vapor may be required for efficient generation of EUV radiation.

The radiation source LA is contained in its own source chamber 10, shown in more detail in Figure 3, to confine those rather high partial pressures to the region of the source. Radiation emitted by the source is subsequently passed from the source chamber 10 to the illumination optics box 20. A filter having a channel structure 11 is incorporated on the optical axis OA in the vacuum chamber wall 15 that separates the source chamber from the illumination optics box. The channel structure 11 comprises adjacent narrow channels 12 separated by walls that are substantially parallel to a propagation direction of radiation emitted by the radiation source LA, the propagation direction being substantially directed along the optical axis OA. The channel structure passes the EUV radiation emitted by the source. At the same time it functions as a flow resistance, or barrier, in between the source chamber and the illumination optics box so as to be able to maintain the illumination optics box, or illuminator box, at a much higher vacuum level (lower pressure) than the source

chamber. The form and length of the channels in the channel structure should be chosen so as to provide a high EUV transparency and a high enough flow resistance.

Figure 3 also shows that the radiation is sort of radial emitted from the elongated region LA. According to the invention, the transparency of the channel structure is increased. To that end the structure is arranged such that the width of the channels in the structure increases along the optical axis OA in the propagation direction of the radiation, both in the plane of the drawing and in a plane perpendicular to the plane of the drawing of Figure 3. In such a configuration the walls of the channels are directed more parallel to the propagation direction of the radiation emitted from the source. The channel structure is rotationally symmetric around the optical axis OA, as is further shown in Figure 4. Figure 4 only depicts about a quarter of the channel structure 11.

Figure 3 and 4 further show that the region LA from which EUV radiation is emitted, is elongated along the optical axis, i.e. it has a finite length along the optical axis. To further increase the transmission of radiation through the channel structure for the whole elongated region that emits radiation, the width wr of the of the channels in a direction perpendicular to the optical axis, i.e. the radial direction RD with respect to the optical axis OA, is chosen considerably larger than the width wt of the channels in a tangential direction TD around the optical axis OA. Figure 4 better shows those width dimensions. In case the channels would have a narrow width in the radial direction RD, only radiation from a very small part from the elongated emitting region LA would be transmitted through the channels, while radiation from other parts would hit the channel walls. Only a small fraction of the radiation energy of the source would then pass the channel structure 11. Figure 3 shows two rays 17 in dotted lines, which are emitted from opposite ends of the elongated region LA, the rays not being parallel and entering one channel. A channel that is to narrow in the radial direction RD would not pass both rays.

The gas flow conductance of the channel structure, or its resistance to gas flow, can be derived as follows. It shows that the result of the division of an opening in a vacuum chamber wall in a number of adjacent channels drastically reduces the conductance of the opening. In a simplified calculation, which is accurate within approximately 10%, the conductance C_T of the channel structure can be written as $C_T = C_M + C_V$, where C_M represents the molecular conductance and C_V the laminar conductance. A further background for such calculations can be found in "Foundations of Vacuum Science and Technology", edited by J.M. Lafferty, Wiley & Sons Inc., 1998, ISBN 0-471-17593-5. For high Knudsen numbers (> 0.5) C_M dominates, whereas C_V dominates for low Knudsen numbers. In the

so-called transition regime, which is the case for the situation considered, both contributions have to be taken into account.

Taking the structure of Figure 4 and assuming that it covers 2.4 steradians at 7 cm distance from the source, it has a surface area of approximately 114 cm^2. For a structure wherein the channels are approximately 20 mm long, 0.5 mm wide in the tangential direction and 20 mm wide in the radial direction with respect to the optical axis and for Xe at a source pressure of 0.1 mbar, holds that $C_M = 50$ l/s, $C_V = 4$ l/s and $C_T = 54$ l/s.

In an equilibrium situation the gas flow through the channel structure equals the flow into a vacuum pump VPI connected to the illuminator box 20:

$$(P_{source} - P_{illuminator}) \times C_T = P_{illuminator} \times S_{eff} \quad ,$$

wherein P_{source} represents the pressure in the source chamber, $P_{illuminator}$ the pressure in the illuminator box and S_{eff} the effective pumping speed of the vacuum pump VPI connected to the illuminator box. Another vacuum pump VPS will generally be connected to the source chamber 10. Aiming at $P_{illuminator} << P_{source}$ one obtains:

$$P_{illuminator} / P_{source} = C_T / S_{eff} = 54 / 6000 = 1/111 = 0.009 \quad ,$$

when having a vacuum pump VPI, such as a turbo molecular pump having an effective pumping speed : $S_{eff} = 6000$ l/s.

The above calculation shows that due to the channel structure a sufficient flow resistance can be reached to have more than a factor 100 reduction in Xe pressure. For the case above the source pressure is at such a low level that the molecular regime dominates. In general, C_M scales with the inverse square root of the molecular mass of the gas considered, and C_V scales with source pressure. For higher source pressures and lower molecular masses the channel structure would be less efficient. By increasing the aspect ratio (ratio of channel length over smallest channel width) of the channels, the resistance can be increased, as required, to regain efficiency. When keeping the aspect ratio constant, the length of the channels can be decreased while keeping C_T constant.

In case the channel structure is positioned closer to the source, its surface area is smaller and its conductance decreases accordingly. A drawback would be vignetting due to the finite dimension of the source and a higher heat load of the source on the channel structure. The channel structure should be made of a suitable material to withstand the heat

load of the radiation source. The walls of the channels are preferably very thin (foils) to present a very low obscuration to the radiation from source LA.

Channels in the middle of channel structure 11 around optical axis OA are not shown in Figure 4. The channels in this part will more or less "see" a point source and it is therefore less important to have a large width in the radial direction RD. The embodiment shown comprises channels having a honeycomb structure as is depicted in Figure 5 in the middle part of the channel structure 11. The diameter of the channels in the honeycomb structure is approximately 0.3 mm and their length approximately 20 mm. For certain source configurations the honeycomb structure might also be employed for the whole channel structure 11.

The radiation source used may emit particles that are detrimental to any optics arranged along the optical axis. Those particles can be charged and/or move with a high velocity. The channel structure as described above will also act as a filter to prevent those particles from reaching the optics, and it need not be incorporated in a vacuum wall to perform such filtering. Particles emitted by the source will become trapped in the channel structure. Such a filter comprising a channel structure as described may be mounted in any manner so as to be able to prevent those particles from reaching components that may be damaged by the emitted particles.

The channel structure shown in Figure 4 behaves as an optical element having a focus point. This means that all radiation emitted from such a point will be transmitted by the structure, with exception of radiation that is hindered by the thickness of the channel walls, or foils. However, the radiation source discussed here is not a point source, but has some extension. For example, the diameter of the source is 1,3 mm. This means that part of the source radiation will be incident on the channel walls. Without further measures, this radiation will be blocked by the walls and thus will be lost. According to another aspect of the invention this radiation loss can be reduced considerably by making the walls reflective for the radiation used. In general, reflection of small wavelength radiation, such as EUV radiation, at a surface is not an easy matter because this requires a very small surface roughness. The invention uses the insight that in the present arrangement of source and channel structure, radiation reaching the walls of the structure is incident on these walls at such small angles that these walls can be made sufficient reflective.

Fig.6 shows a symmetric radiation source LA, which is arranged symmetrically with respect to the channel structure. The channel structure is represented by a horizontal wall 60 and a vertical wall 62. Radiation 64 from a point A of the source is

reflected by a wall 62 as radiation 66 at an angle θ with the wall. The direction of radiation 66 is such that it seems to originate from point B. Point B forms also part of the source volume so that radiation 66 coincides with radiation 68 from source point B. This demonstrates that radiation reflected by a wall of the channel structure can be regarded as originating from the source volume and thus can be used as part of the projection beam.

The angle of incidence of radiation 64 on the wall 62 is such that this wall is sufficient reflective. For example, for the case that the channel structure is positioned 70 mm from the source, the thickness of the walls (foils) is 0,1 mm and the source diameter is 1,3 mm, the maximum angle of incidence θ_{max} is given by:

$$\theta_{max} = \arctan [(1,3 - 0,1)/ 2x70] = 0,5^0.$$

Such a small angle of incidence is a grazing angle.

To achieve sufficient reflection of the walls for EUV radiation, these walls are coated with a layer of molybdenum. This material is also used in mirrors for EUV radiation having a wavelength of 13,5 nm. Fig.7 shows the reflection coefficient R for 13,5 nm radiation of the materials molybdenum, ruthenium, tungsten and iron at a grazing angle of $0,5^0$ as a function of the rms surface roughness σ of the wall surface. For a surface roughness up to 50 nm the reflection coefficient for molybdenum and ruthenium is rather high, so that coating the walls of channel structure will produce a significant effect.

For wall plates made of stainless steel the surface roughness of 50 nm can easily be obtained by simple polishing with sandpaper having grain 500.

The debris from the source may consist mainly of sputtered molybdenum particles. These debris particles will be deposited on the channel walls. Since molybdenum is a good EUV reflector deposition of molybdenum particles will not influence the reflection, provided that these particles remain small.

Whilst a specific embodiment of the invention is disclosed above it will be appreciated that the invention may be practiced other than described. The description is not intended to limit the invention. For instance, the channel structure may be employed with other gases to present a flow resistance and a decreased flow conductance accordingly. Further, the channel structure may be incorporated in a vacuum wall separating other vacuum chambers, such as in the vacuum wall separating the projection optics box and the substrate chamber to present a barrier to contaminants that may escape from the radiation-sensitive resist layer on the substrate upon exposure. Also the considerations with regard to the

channel width along the optical axis for a diverging beam of radiation may hold at other locations. For a converging beam of radiation the width of the channels should decrease along the optical axis in the propagation direction of the radiation. Since elongated images of the elongated source may be formed at locations on the optical axis, the considerations with regard the widths of the channels in the radial and tangential directions with respect to the optical axis will also hold at those locations.

CLAIMS:

1. An illumination system comprising:
a radiation source constructed to generate a beam of radiation, and
two vacuum chambers separated by a chamber wall incorporating a channel structure comprising adjacent narrow channels separated by walls that are substantially parallel to a propagation direction of said radiation so as to pass said radiation from one of said vacuum chambers to the other one, said propagation direction being substantially along an optical axis of said apparatus, characterized in that a width of said channels increases or decreases along said optical axis in accordance with passing of a diverging or converging beam of radiation, respectively.

2. An illumination system as claimed in claim 1, characterized in that said channel structure comprises a honeycomb structure.

3. An illumination system as claimed in claim 1 or 2, characterized in that a cross-sectional dimension of said channels in a radial direction perpendicular to said optical axis is larger than another cross-sectional dimension of said channels in a tangential direction around said optical axis.

4. An illumination system as claimed in claim 3, characterized in that said width in the tangential system direction is in the range from 0.1 to 2 mm, preferably 0.2 to 0.7 mm.

5. An illumination system as claimed in claim 3 or 4, characterized in that said width in the radial direction is in the range from 5 to 50 mm, preferably 10 to 30 mm.

6. An illumination system as claimed in any one of the claims 1 to 5, characterized in that a length of said channel is in the range from 5 to 70 mm, preferably 10 to 40 mm.

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7. An illumination system as claimed in any one of the claims 1 to 6, wherein said apparatus further comprises a radiation source contained in one of said vacuum chambers.

8. An illumination system as claimed in any one of the claims 1 to 7, wherein said radiation source is a plasma source for generating extreme ultraviolet radiation.

9. An illumination system as claimed in claim 8, characterized in that said radiation source is a discharge plasma source.

10. An illumination system as claimed in any one of the claims 1 to 9, characterized in that the radiation is extreme ultraviolet radiation having a wavelength in the range from 0.5 to 50 nm, preferably 5 to 20 nm.

11. An illumination system as claimed in any of claims 1-10, characterized in that the channel walls are reflective for the projection beam radiation.

12. An illumination system as claimed in claim 11, characterized in that the channel walls are coated with a molybdenum layer.

13. A lithographic projection apparatus comprising:

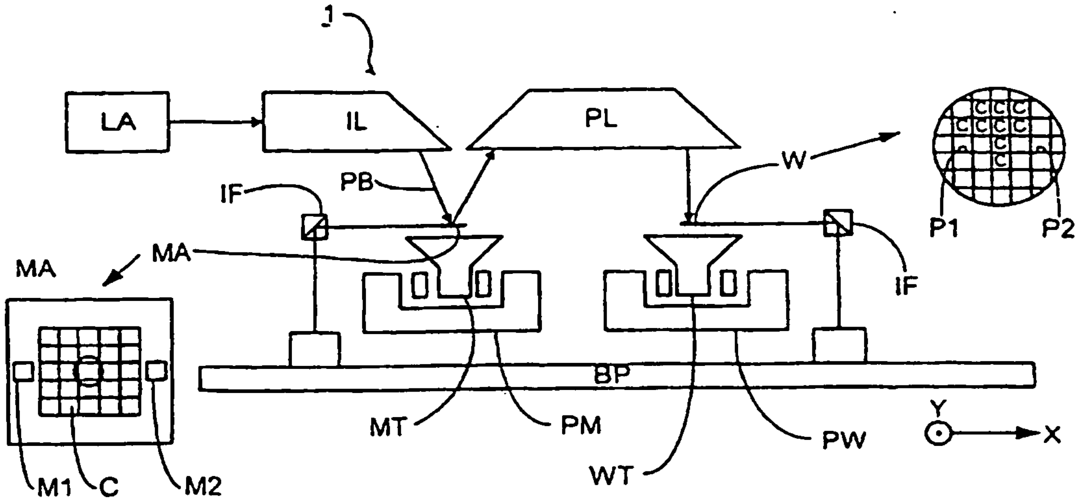
- an illumination system constructed and arranged to supply a projection beam of radiation;
- a mask table constructed to hold a mask;
- a substrate table constructed to hold a substrate; and
- a projection system constructed and arranged to image an irradiated portion of the mask onto a target portion of the substrate; characterized in that the illumination system is a system as claimed in any one of claims 1-12.

14. A method of manufacturing a device comprising device features in at least one layer of a substrate , which method comprises at least one set of at least the following successive steps:

- providing a mask pattern comprising pattern features corresponding to device feature to be configured in said substrate layer;

- illuminating the mask pattern by means of an illumination system;
- imaging the mask patter by means of a projection system in a resist layer coated on the substrate;
- developing the resist layer, and
- removing material from or adding material to substrate areas, which areas are delineated by the pattern configured in the resist layer, characterized in that use is made of an illumination system as claimed in any one of claims 1-12..

15. A device manufactured by means of the method of claim 14.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M2
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P2
C

FIG. 1

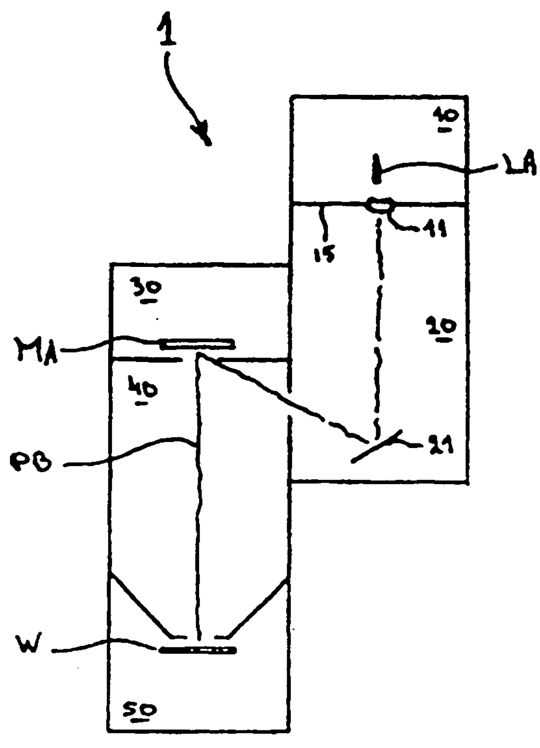
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FIG. 2

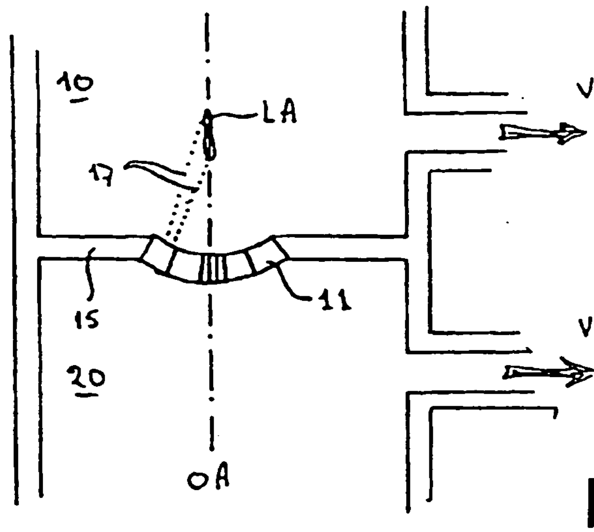

FIG. 3

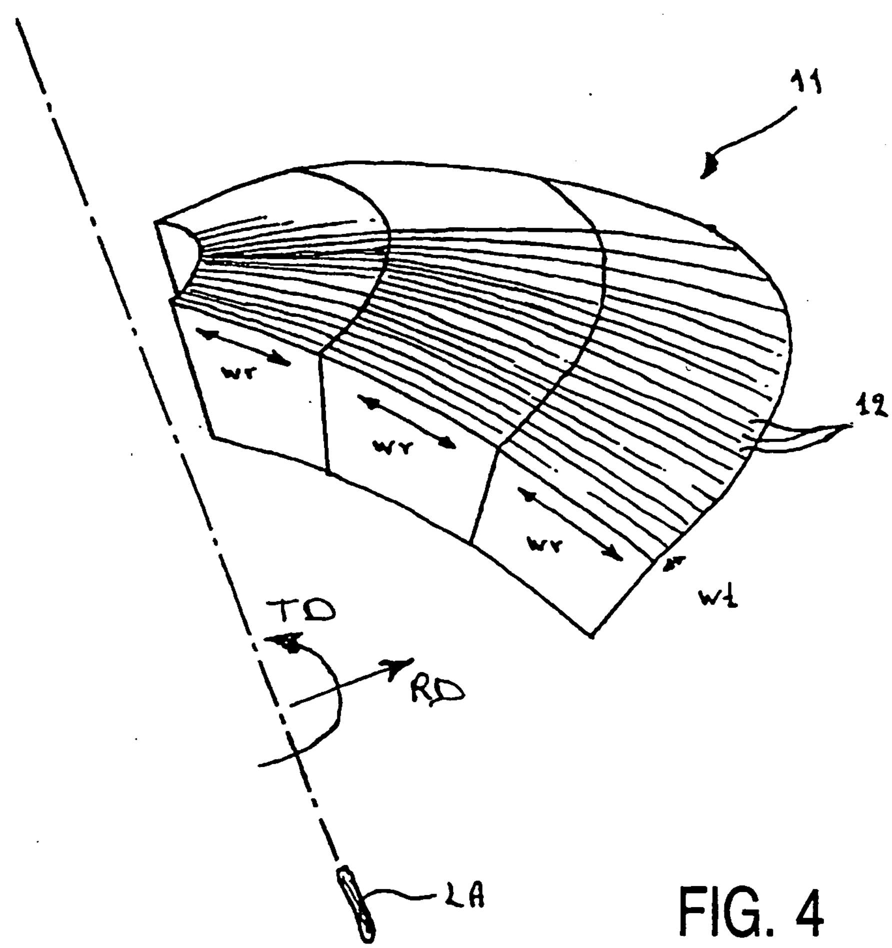

FIG. 4

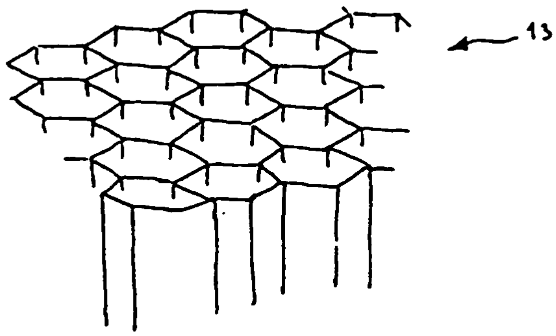

FIG. 5

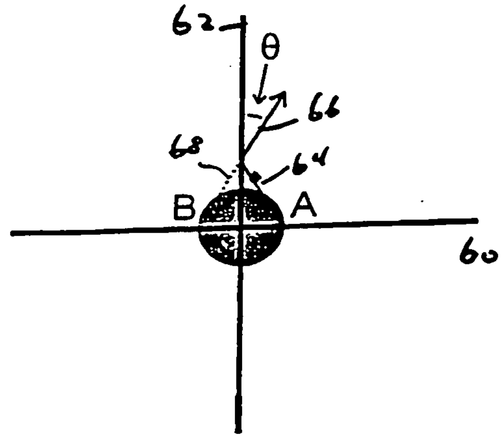

FIG. 6

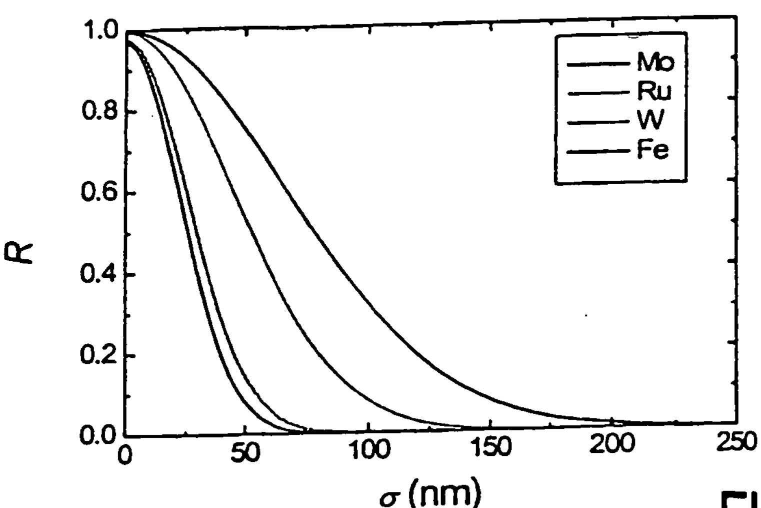

FIG. 7

BNSDOCID: <WO 02054153A1_I_>

INTERNATIONAL SEARCH REPORT

Intern Application No
PCT/IB 01/02710

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G03F7/20 G21K1/02 H05G2/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G03F G21K H01J H05G H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	US 4 825 453 A (INAGAKI AKIRA ET AL) 25 April 1989 (1989-04-25) column 2, line 48 - line 59 column 4, line 15 - line 17 figure 1	15
Y	 ---	1-14
	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
24 May 2002	05/06/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Heryet, C

INTERNATIONAL SEARCH REPORT

Internal Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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JP 62016525	A	24-01-1987	NONE			